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Topology optimization for maximizing the fracture resistance of quasi-brittle composites

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Abstract

In this paper, we propose a numerical framework for optimizing the fracture resistance of quasi-brittle composites through a modification of the topology of the inclusion phase. The phase field method to fracturing is adopted within a regularized description of discontinuities, allowing to take into account cracking in regular meshes, which is highly advantageous for topology optimization purpose. Extended bi-directional evolutionary structural optimization (BESO) method is employed and formulated to find the optimal distribution of inclusion phase, given a target volume fraction of inclusion and seeking a maximal fracture resistance. A computationally efficient adjoint sensitivity formulation is derived to account for the whole fracturing process, involving crack initiation, propagation and complete failure of the specimen. The effectiveness of developed framework is illustrated through a series of 2D and 3D benchmark tests.

Keywords: Fracture resistance, Topology optimization, BESO, Phase field method, Crack propagation

1. Introduction

Composite materials are usually made of two or more constituent materials with variant mechanical properties and have advantageous overall characteristics when compared to traditional materials. The overall behavior of composite materials, such as fibrous composite, concrete, metallic porous material and metal alloy, depends strongly on the size, shape, spatial distribution and properties of the constituents. Seeking for an optimal design of spatial distribution of the constituents in heterogeneous media has recently attracted a growing attention (see e.g., [1–4]).

Among all properties of interest, accounting for material failure is of essential importance in the design of composite materials. As illustrated in Fig. 1, it is desired to improve the fracture

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